Thermal Sensation and the Skin Sensation Test: Regional Differences and Their Effects on the Issue of Reliability of Temperature Ranges.

This study assesses the differences in temperature sensitivity of skin areas. The subjects were required to associate the water content of test-tubes with the different heat sensations. The side of the test-tube was placed on the skin area and the temperature was matched with the subject's response. Analyses were limited to the warmth and cold sensations as generalizations can be made from these in terms of differences in the skin areas in heat perception. In the face, the temperature associated with warmth was significantly lower than in the forearm and the leg. This trend was different between the three areas in terms of the cold temperatures.

The intra-individual difference suggests that results of skin sensation tests should be interpreted with some caution.

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The Skin Sensation Test (SST) is a standard routine procedure when applying heat in physiotherapy practice. The tendency, however, has been for both instructors and clinicians to neglect the aspect of this vital procedure which concerns the possibility of significant regional differences in sensation to heat and cold between skin areas of the body. These differences arise because of the irregularity of the somatosensory representations of the skin areas overlying the regions (Goldstein 1980, Martin 1981), and due to the differential vascularity of the areas concerned (Berne and Levy 1972).

The effect of the differences in the sizes of the representation in the somatosensory cortex would be that of differing thermal sensitivity between different skin areas of the body. The face, with its remarkably larger representation on the sensory homunculus should display a significantly higher sensitivity than say, the forearm and the leg, these areas being relatively less represented in the sensory cortex. Thermal sensations produce vasodilatation effects for heat and vasoconstriction for cold.

Recent studies on the issue of the reliability of a set of temperture ranges have tended to conclude that 40°C might be a more reliable temperature for the sensation of warmth, as suggested by Owoeye (1983), without the additional specification of regional differences in the body.

It is also known that through the mechanism of transduction, thermal stimuli that are strong enough may alter the local environment of the sensory terminal such that temperatures above 40°C may produce the sensation of pain, instead of just warmth (Yaksh and Hammond 1982). They also suggested that the release of a chemical intermediary in the internal structure of the thermoreceptive terminal activates the transduction mechanism. The perception may therefore resemble that of nociception. Nociceptors *per se* may also be stimulated.

The Somatosensory System and Mediation of Thermal Sensation

The somatosensory system is made up of the skin senses of touch, pressure, vibration, itch, temperature, pain and tickle, and the body senses of joint position, muscle tension, and visceral state. There are two neocortical bodies recognized as the somatosensory recipient areas; the primary somatosensory cortex (SI) which corresponds with the post-central gyrus (areas 1, 2, 3); and the secondary or supplementary somatosensory area (SII) which is said to be located on the superior bank of the sylvian fissure (area 43). The two areas receive sensory information for more processing. The amount of cortex devoted to a body area is directly proportional to the sensitivity of that region (Kolb and Whishaw 1980). In this regard, the hand and face areas are accordingly much more represented in both SI and SII, than say, the forearm and the leg.

There are however differences in the SI and SII regions. The SI area controls contralateral sensory functions while SII controls both contralateral and ipsilateral areas. Two distinct sensory pathways subserve the areas; SI receives its input from the lemniscal system through the ventral basal system of the thalamus, and SII gets its inputs from the spinothalamic or extralemniscal system through the ventral basal complex as well as the posterior thalamus.

Thermal sensation is mediated by cold and warm receptors (Martin 1981). Warmth is mediated by unmyelinated fibres, whereas cold is mediated by A δ fibres only.

Thermal sensations produce cardiovascular responses which either result in cutaneous vasoconstriction (in response to cold) or vasodilation (in response to heat). The response to cold is more pronounced in the hands and feet than elsewhere (Berne and Levy 1972). The vasodilator effect of heat seems to be the same for all parts of the body.

The purpose of this study, therefore, was to examine more quantitatively the differences between the skin areas overlying the face, forearm and the leg in terms of thermal sensitivity.

Method

Eighteen (9 female, 9 male) healthy students in the Department of Physiotherapy, College of Medicine of the University of Lagos, served as subjects in this study. The age of the group ranged from 18 to 27 years (Mean = 22.72 years, SD = ± 1.83).

The purpose and technique of the study was explained to each subject prior to the actual testing. The subjects were all certified to be in good state of health, and skin integrity was confirmed by inspection.

The materials for the study were a Celsius thermometer, ice chips, test-tubes and some water at different temperatures. As is common with other investigations of cutaneous sensation (Owoeye 1983, Nolan 1985), the area to be tested was first exposed and carefully inspected. The subject was then instructed on what to expect and what and how to report on this experience. Then the subject closed his or her eyes while the side of the test-tube was placed in contact with the preselected area of the skin. The test-tube was placed in contact only briefly, until a response was made by the subject in terms of the perceived sensation. The maximum period of contact was not more than 3 seconds. Two trials were done on each skin area. The areas tested in all subjects were the face, the forearm, and the lower leg. In the face, the area studied was mid-way on the lateral mandible, while in the forearm, the skin area examined was the anterior surface mid-way between the elbow and wrist joints. In the leg, the area studied was the skin overlying the peroneal group of muscles, mid-way between the knee and the lateral malleolus. These areas (the face, the forearm and the leg) were selected on the basis of the varying sizes of their somatosensory representations.

Throughout the subject was in the supine position because of the multi-area coverage design.

As a routine precautionary step (in order to enhance internal validity), records were kept of tap water temperature being used as well as the temperature of the environment. The precise time of testing was recorded.

In order to reduce the possibility of carry-over of preceding sensations, no one test-tube was applied to more than one skin area during one set of trials, and contact with the same spot on the skin was avoided. The latter step was taken in order to avoid the possibility of physiological accommodation to the test stimuli.

In the testing procedure, three test-tubes were used and each contained tap water, cold water and hot water respectively. The temperatures of the latter two test-tubes were either raised or lowered gradually, through the addition of warm or cold water respectively. An upper limit of 50°C and a lower limit of 15°C were set for this study. At a regular interval of 1°C (upwards or downwards), depending on whether the temperature was low or high, the subject was required to identify the sensation (hot, warm, normal or cold) associated with the test-tube in contact with the skin. All tests in the study were performed by one examiner.

Results

The major aim of this study was to examine the differences in heat sensitivity of three regional areas of the body. The results presented below are in two sections. The first section describes the minor differences observed in sensitivities due to testing times of the day and the effect of both environmental and tap water temperatures. The second section presents the main findings of the study with the statistical analyses.

Testing times of the day were mainly in the mornings (between 10.16 a.m. and 11.30 a.m.) and in the afternoons

Table 1:
Mean warm temperatures for the different test periods

Body Area	*Test Periods*	
	Morning	*Afternoon*
Face	33.26°C (N = 10)	34.36°C (N = 8)
Forearm	34.50°C (N = 10)	36.42°C (N = 8)
Leg	40.21°C (N = 10)	42.34°C (N = 8)

Table 2:
Tap water and environmental temperature data

Test Times	*Temperature Ranges (° C)*	
	Tap Water	*Environment*
Morning (10.16 — 11.30 am)	27.00 — 28.50	28.00 — 28.50
Afternoon (12.30 — 3.00 pm)	28.00 — 28.50	28.00 — 30.00

(between 12.30 p.m. and 3.00 p.m.). Testing time could not be standardized because of subject availability and/or space and equipment availability in the department where the experiments were carried out. Environmental temperature was expectedly different from that of tap water both in the mornings and in the afternoon. Environmental temperature was higher than tap water temperature both in the mornings and in the afternoons. Tap water had a temperature of between 27.00°C and 28.00°C in the mornings and then between 28.00°C and 28.50°C in the afternoons. This slight increase in temperature only seems to be connected with the tropical changes in temperature from a colder morning to a fairly warm afternoon. Equally, the environmental temperature varied between 28.00°C and 29.50°C in the mornings and between 28.00°C and 30.00°C in the afternoons. Our observations in terms of these temperature values were such that the sensitivity ranges tended to fluctuate with the temperature. The values of the warmth sensation were therefore lower for all regional areas of the body in the mornings than in the afternoons (Tables 1 and 2). This trend was not the same for the cold sensation, as cold temperatures were lower in the afternoons than in the mornings.

Regional Comparison of Sensitivity

For statistical analysis, a three (regions) by two (trials) factorial design anova was used to determine differences between the regional areas within the subjects. These analyses revealed a significant difference between the face and the leg, F (1, 35) = 12.66, $p < 0.001$, for the warm sensation. The temperature associated with the sensation of warmth was lower in the face than in the leg (see Appendix). The subjects all reported a mean higher temperature for this sensation in the leg than in the face. Analysis in terms of the cold sensation did not reveal any significant differences. In connection with this sensation, the results suggest that there are no differences in perception between the face and the leg. A similar comparison did not reveal any significant differences between the face and the forearm, nor between the forearm and the leg. However, a significant proportion of the subjects reported a lower temperature range for the face than the forearm and leg ($\chi^2 = 6.6$, $df = 1$, $p < 0.001$) (see Table 3), while almost the same proportion of subjects reported a significiantly higher temperature range for the leg compared with the face or the forearm ($\chi^2 = 4.5$, $df = 1$, $p < 0.05$). The proportion of subjects correctly identifying the higher temperature with the forearm, compared with the face, was also signficant ($\chi^2 = 12.93$, $df = 1$, $P < 0.001$).

These latter findings all support the differences between the regional areas, reported in this paper.

)iscussion

The hypothesis that there are regional differences in the body in terms of thermal sensitivity has been tested in healthy under-graduates.

For all subjects, the face showed a significantly higher temperature sensitivity (lower temperature range detected) than both the forearm and the leg. This is in agreement with our prediction as well as in line with previous studies (Goldstein 1980, Nolan 1985). This is however not entirely surprising in view of the fact that the somatosensory area of the face is almost twice that of the forearm and the leg on the somatosensory homunculus (Goldstein 1980). We are not surprised, along this same line of argument, that the leg was not significantly different from the forearm, as they have just about equal somatosensory representations. In fact, examination of the values of mean temperatures of the forearm and the leg for comparison shows a smaller difference than a similar comparison between the face and the leg (Table 3).

Table 3:
Combined comparison of mean temperature values in the three regional body areas

Body Area	*Skin Region*	*Mean Temperature*	
		Warm Range	*Cold Range*
Face	Midway, over lateral mandible	34.33 (±1.63)	20.89 (±0.91)
Forearm	Anterior surface, midway between elbow and wrist	36.44 (±1.78)	21.67 (±2.70)
Leg	Midway over peroneal group	38.61 (±1.94)	22.16 (±2.40)

The difference between the face and the leg becomes even more important in view of the psychophysical relationship between warm receptors and heat sensation; a 5°C increase in temperature results in almost 10 times magnitude estimation of the associated heat perception (Goldstein 1980, Martin 1981). What this means therefore is that the sensitivity of the face is such that the lower temperature is associated with about the same intensity of heat identified in the leg. This is further supported by the relatively larger somatosensory representation of the face.

Our observation in terms of lower temperature sensitivity in the mornings for all three areas of the body agrees with findings of previous studies on skin sensitivity (Markhworth 1953, Sinclair 1973). Although sensitivity diminishes when the environmental temperature decreases, *ie* in the mornings and it increases when environmental temperature increases *ie* in the afternoons, these differences may not be enough to warrant separate SST for the same patient who changes treatment times between the mornings and afternoons except perhaps in some conditions where skin sensitivity is defective or liable to changes which must be carefully watched. This could happen in a peripheral nerve disorder where there is hyperaesthesia or anaesthesia, as associated fluctuating problems, accompanied with pain. Heat treatment can then become dangerous in this situation unless proper care is taken. So, as a precaution against thermal burns in such cases, especially for the defaulting patient who reappears with the same diagnosis, a separate SST is suggested where a change is made in the time of treatment. The SST, as well, can be a partial prognostic tool. It can be used to assist the determination of the responses to treatment, especially in cases where thermal perception is expected to improve as in peripheral neuropathy where regeneration occurs.

It is suggested in some circles that the age of the test subject affects sensation discriminability (Sohn and Simons 1980). The limited age range of the small sample in the present study was 18 to 27 years; this only provided information on a very restricted subset.

Contrary to the conclusions of Owoeye (1983) regarding the reliable temperature being 40°C for the sensation of warmth, our present study indicates a lower temperature (around 33°C) which agrees with Martin (1981). In addition, at temperatures of 40°C and above, the sensation of pain is said to be experienced instead of just warmth. The explanation as stated earlier, may be that, through the mechanism of transduction, adequately high thermal stimuli cause the afferent terminals to release a chemical internal intermediary, and this elicits the sensation of pain, instead of warmth. It is possible also, that at this temperature range (*ie* 40°C and above), nociceptors are stimulated. In this study, no subject experienced pain for the temperature ranges that were tested perhaps because the test tube was in contact with the skin for only a brief period. In respect of the face the temperature perceived as warm is clearly lower (34.33°C, SD = 1.63) (see Table 3). The difference between our study and that of Owoeye (1983) may be ascribed to the fact that he conducted his study on the forearm only; he did not compare the effects of regional differences as we have done in this study. We have also carried out more detailed analyses of the temperatures associated with warm as well as cold sensations as these, in our opinion, could allow us to generalize in terms of support or non-support of the previous study by Owoeye (1983), as regards temperature ranges. Our results point to a non-support of the study by Owoeye (1983). Contrary to his generalizations, the reliable temperature associated with warmth (40°C) is modified by the skin area investigated: it is lower (34.33°C) in the face, for instance.

No differences were observed between the face and the other areas for the cold sensation. This is contrary to our expectatons considering the difference in the sizes of the representation of these areas in the somatosensory cortex (see Table 1).

Conclusion

The differences in the sensitivities of the face, forearm and the leg are based on their differential somatosensory representations and probably also on their differential vascularization. Heat perception therefore seems to be higher in the face than in the forearm and leg. Perception of the cold sensation however does not seem to vary for the three skin areas. It is possible that the restricted coverage of the facial area did not elicit the vasoconstrictive reflex noted with the face. This probably explains why the face was not characteristically different from the other areas.

The clinical and practical implication of these results is that in applying the skin sensation test, the results must be interpreted with caution for the different regional areas of the body.

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Appendix

Data of mean temperature indentified by subjects†

	Cold			Warm		
	Body Regions			Body Regions		
Subject	*Face*	*Forearm*	*Leg*	*Face*	*Forearm*	*Leg*
1	21	23	23	34	36	39
2	20	23	23	34	37	39
3	20	34	25	32	35	38
4	21	23	23	35	36	38
5	20	23	21	33	37	39
6	20	23	22	34	35	39
7	20	21	23	34	35	38
8	20	21	23	36	35	38
9	21	21	22	34	38	38
10	20	21	23	38	39	38
11	21	23	21	32	39	38
12	22	22	23	33	38	39
13	23	22	22	36	39	40
14	22	23	23	34	38	40
15	22	21	23	35	39	41
16	20	21	22	33	38	36
17	21	21	23	37	40	38
18	22	23	24	34	40	40

†Raw data for the Cold and Warm sensations only are shown as analyses were limited to these two.